Post-fire changes of Soil Water Retention Capacity in a Mediterranean shrubland soil. Under canopy and bare soil microenvironments

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1. Abstract

One of the key effects of fire on soil is the induced changes in its structural and hydrological characteristics that, in many cases, can favour the intensification of water erosion processes. These effects could be more important if it is taken in to account that, in the last years, the incidence of fires on areas already affected and in a recovery state, has been increased almost exponentially in the Mediterranean area. Under this scope, this work studies the changes induced on Soil Water Retention Capacity (SWRC) by repeated fires in a Mediterranean shrubland soil, and considering two specific enviroments: under canopy (UC) and on bare soil (BS).

This study was developed in the experimental field station of La Concordia (Casinos, Spain), in a set of nine erosion plots (20 x 4 m^2) located in a SSE oriented hillside, in Valencia (Spain).

In 1995, experimental fires were carried out to simulate the effect of two different fire intensities (high and moderate). Three plots were used in each fire treatment, and the remainders were left unaltered to be used as control. During 8 years the plots were maintained undisturbed allowing its recovery. In 2003, new experimental fires were performed to simulate the incidence of repeated fires, in the previously burned plots. These last fires reached low intensity in all cases.

From 2003 to 2006, and twice a year (winter/summer), the plots were sampled. Four samples of the first 5 cm soil were taken on each plot, two under canopy (UC) and two on bare soil (BS), giving a total of 12 samples per treatment. The SWRC was calculated by Richard's method, using the pF2 as field capacity and pF4.2 as the permanent wilting point.

Before 2003 fires, statistically significant differences between environments (UC/BS), in each treatment, were observed. After the experimental burnings values of SWRC were homogenized in UC and BS environments, at least, until 3 years after burning. In control plots, significant statistical differences among UC and BS sites were obtained, mainly in summer. Just after fire, SWRC in the burned plots decreased ≈10% below control values. However, one month after fire, these differences were attenuated.

2. Introduction

An important characteristic of the Mediterranean climate is the presence yearly of long summer periods of water deficit due to the absence of rains and the high temperatures. These climatic variations are more intense in the semi-arid areas of the Mediterranean region, which are more sensitive to desertification. This fact favours high potential evapotranspiration rates, which maintain the soil in dry conditions during long time periods. Soil moisture dynamics depends, mainly, on the presence or absence of vegetation, soil texture, soil organic matter, soil crust, soil stoniness and variations in soil characteristics combined with the effect of micro-topographic features (Fitzjohn et al., 1998). According to these factors, soil can either lost or retain water. In conditions of dryness or water shortage, soil moisture pattern is very disordered and its distribution appears to be very complex, having both spatial and temporal variability (Williams et al., 2003).

Regarding soil microclimate, the importance of soil moisture and, hence, soil water retention capacity, is decisive because it influences positively the vegetation growth, soil biological activity, soil structure and infiltration.

The characteristic patchiness of the Mediterranean shrubland vegetation, like that developed on the study area (La Concordia, Spain), influences directly soil moisture patterns. When fire reaches vegetated areas, the input of organic matter, litter and ashes promotes physical and chemical changes in the upper soil layers. The clearing spaces (bare soil), usually show low organic matter content, less aggregate stability and a lower mean weight diameter of soil particles (Campo et al., 2007) and then, the effect of the temperature impact can produce changes at different levels. Thus, depending on the fire intensity and the microenvironments affected, different soil responses will be produced, as was reported by Pierson et al. (2001). Therefore, it is important to distinguish between vegetated/non vegetated microenvironments (under canopy and bare soil) to perform a more accurate soil wetness characterization. To study the temporal variations on soil surface hydrological properties induced by the fire impact, Rubio et al. (2003) suggested that one of the best ways is through the performance of experimental fires. In this context, the aim of this study is to asses the impact of repeated experimental fires, on the soil water retention capacity (SWRC) at under canopy (UC) and bare soil (BS) micro-scale, and to analyze its response in a three year period.

3. Materials and methods

This research was carried out at the Permanent Experimental Field Station of La Concordia (Llíria-Valencia, Spain), 50 km NW of Valencia city. It is 575 m above sea level, on a hillside facing SSE with an average slope of 40%. The Experimental Field Station comprises a micritic grey cracked limestone which has developed a Rendzic Leptosol (González et al., 2006). The texture is sandy-loam and the aggregate stability ranges between 32-40 %. The soil organic matter (SOM) is around 10%, the water holding capacity is ≅22% and the pH is 7.5. The soil profile shows a variable depth, no more than 50 cm, high superficial (≅65 %) and subsuperficial stoniness (≅ 40%), good drainage and important microbiological activity showed by frequent and discontinuous soil pores. Average annual precipitation in the area is 400 mm with two maximums, autumn and spring, and a dry period from June to September. Mean monthly temperatures range from 13.3 to 25.8ºC.

The Experimental Field Station consists on a set of nine erosion plots (20 x 4m) with similar characteristics such as soil, slope gradient, rock outcrops and vegetation cover. In 1995, a set of experimental fires was carried out. Two fire intensity treatments (high and moderate) with three plots each were obtained, the remainders plots were left unaltered. During 8 years the plots were maintained undisturbed. In 2003, experimental fires were performed again in the previously burned plots, to simulate the incidence of repeated fires. These last fires reached low intensity in all burned plots (González et al., 2006).

Sampling periods were conducted, twice a year, from before the 2003 experimental fire until the year 2006. The seasonal samplings were made in the winter 2003 (January 2003), winter 2004, summer 2004, summer 2005, winter 2006 and summer 2006. In the 2003 repeated fire, additional samplings were made; before the fire (summer 2003 BF), immediately after the repeated fire (summer 2003 AF), and a month after the fire (summer 2003 MAF). In each sampling period a total of 36 soil samples (four per plot) were taken from the first 5 cm of the soil surface. These samples were taken from under canopy (UC) and bare soil (BS) microenvironments. After that, they were air-dried, screened to remove the fraction > 2 mm diameter and stored in plastic boxes until analysis.

The pF curves (pF 1, 2, 2.5, 3.5, 4.2) and SWRC with field capacity at pF2 and wilting point at pF4.2 were calculated for each soil sample and treatment (Richards, 1947).

4. Results

Table 1 displays the SWRC values depending on the treatment and the sampling periods. Figure 1 shows the soil water content in summer 2003, immediately before the fire (summer 2003 BF), and after the fire (summer 2003 AF), depending on treatment (burned and control) and microenvironment (UC and BS).

Before the 2003 fire, in winter 2003 (January 2003) and summer 2003 BF, statistically significant differences between environments (UC/BS) in the control treatment were observed. The samples collected on BS showed major SWRC. In the burned plots, BS samples displayed slight increases in the SWRC.

In summer 2003 BF, the pF curves showed higher soil water content at pF2 in BS samples than in the UC ones. Immediately after the fire incidence (summer 2003 AF), the tendency changed and the soil water content at pF2 in UC was higher than in BS. Immediately after burnings, a decrease in SWRC of ≈10% below the values of the control plots was detected. The post-fire SWRC changes could be related with variations in the soil water content at pF2. At low pF values, as pF2 (field capacity), the amount of water depends primarily on the capillary effect and the pore-size distribution, and hence, it is strongly affected by soil structure (Hillel, 1980).

The repeated fire impact on soil surface put the values of SWRC in UC on a level with the BS ones. In burned plots, non statistical significant differences appeared between microenvironments in the whole studied period. Although, after the fire impact (summer 2003 AF), the tendency changes and a slight increase in SWRC values were obtained in the UC sites. Agreeing with Mallik et al. (1984), after a fire impact, major SWRC is obtained on UC sites. It is possibly due to the clogging processes on soil pores triggered by the remanent ash layer that usually decrease infiltration but increases the SWRC.

One month after the experimental fires (summer 2003 MAF), the tendency changed again, and a high SWRC appeared in BS samples. In this period, the burned soil reached the greatest values SWRC. This sudden change, could be related with the torrential rains occurred ten days following the fire (González et al., 2006), where major runoff and soil losses occurred in burned plots. Barthès and Roose (2002) describes that the soil susceptibility to runoff and erosion is linked to topsoil aggregate resistance to slaking. In dry soils, the slaking is the main mechanism causing breakdown of aggregates. Consequently, heavy rains in summer could have detached and transported superficial soil particles affecting structural and hydrological soil properties.

The initial tendency on control plots is maintained, showing the usual seasonal variations of SWRC, as was reported by Boix-Fayos (1997). Statistical significant differences appeared mainly in summer but not in winter. On summer, the differences between UC and BS on burned plots, increased. In winter, practically same SWRC values were obtained in UC and BS.

Table 1 SWRC (%) depending on the treatment (burned and control), and on the different sampling periods. Values not sharing the same letter in rows indicate significant differences according to Tukey´s test (0.05). UC, under canopy, BS, bare soil, BF, before fire, AF, after the fire, MAF, a month after the fire

Sampling period	Burned		Control	
	UC	BS	UC	BS
Winter 2003	20.74a	21.60a	19.08b	21.87a
Summer 2003 BF	21.50a	23.06ab	21.24a	24.09b
Summer 2003 AF	23.77ab	22.61a	25.16ab	25.98b
Summer 2003 MAF	25.45a	26.88a	23.35a	25.21a
Winter 2004	21.27a	21.30a	20.48a	22.69a
Summer 2004	22.52ab	23.70b	21.18a	23.73b
Summer 2005	21.07ab	22.99b	19.79a	22.59b
Winter 2006	22.16a	22.08a	19.26b	21.48ab
Summer 2006	22.09ab	22.87b	20.56a	25.22c

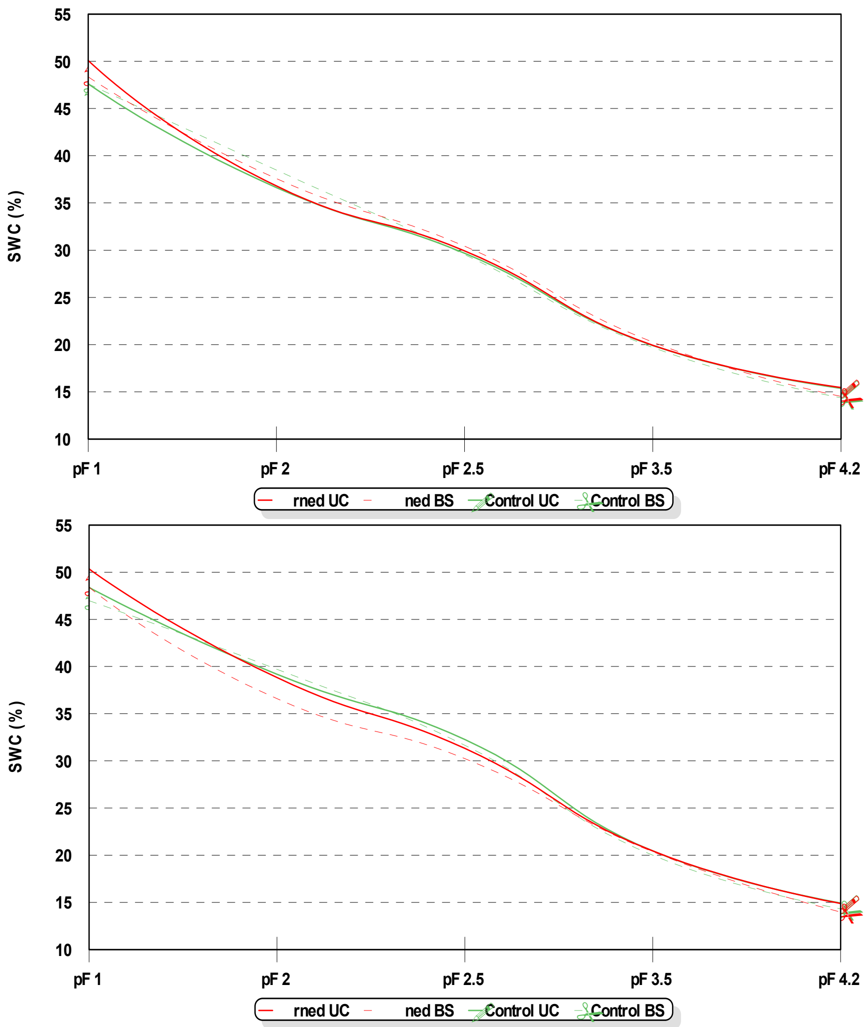

Figure 1 Soil water content (by pF curves) depending on treatment (Burned and Control) and microenvironment (UC, under canopy and BS, Bare soil). Up, summer 2003 before fire and down, summer 2003 after fire

5. Conclusions

The soil not affected by fires showed the usual seasonal variability on SWRC, with major differences between UC and BS on summer samplings. In winter, differences in SWRC between microenvironments were reduced and non statistical significant differences became visible. The fire impact put on the same level the values of this parameter between microenvironments, being these differences minimum in winter and maximum in summer. The major SWRC variations were observed in the burned plots, mainly in the periods directly related with the 2003 experimental fires (summer 2003 BF, summer 2003 AF and summer 2003 MAF). The fire impact affected soil water content mainly at pF2 (field capacity), where soil water retention primarily depends on the soil structural properties.

The changes induced by forest fires on soil hydrology favour a state of major fragility during, generally, one month after the fire impact. These circumstances are accentuated in the Mediterranean area, where the forest fires usually occurs in summer and are immediately followed by a period of torrential rains, which favours the enhancement of the erosion processes and the advance of desertification.

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